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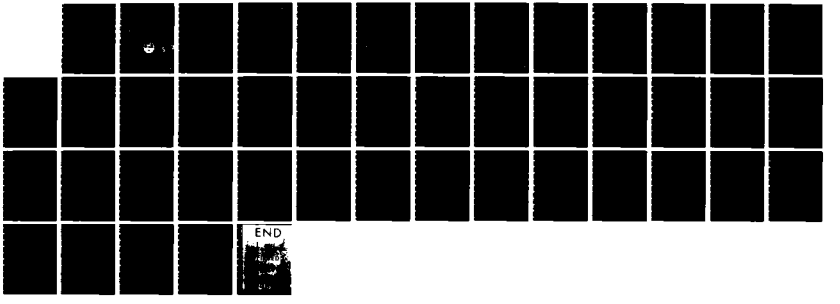

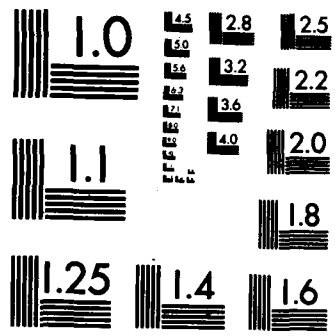

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GUIDE TO THE DEVELOPMENT OF A HUMAN FACTORS ENGINEERING DATA RETRIEVAL SYSTEM

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This report describes the functional specifications for the development of a human factors engineering (HFE) data retrieval system to be used by system acquisition managers, designers, and HFE specialists. The system is organized around the following requirements: The system must (1) be responsive to the needs of a variety of users, (2) include data of the type presently available in MIL STD 1472C plus quantitative estimates of human performance, maintenance and logistics data, specifications and standards, and

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analytical and evaluational techniques, (8) include data from operational Navy sources not presently found in any HFE data base, (9) be formatted in three "tracks," with Track 1 consisting of abstracts of individual studies, Track 2 containing data from the same sources but in a highly synthesized form, and Track 3 containing all other ancillary information such as HFE specifications and standards.

FOREWORD

This effort was conducted in response to problems discussed in General Accounting Office Report PSAD-81-17 and Naval Research Advisory Committee Report 80-9 concerning the lack of emphasis and effective use of human factors engineering (HFE) technology during the weapon system acquisition process. The development of a HFE data base, the characteristics of which are described in this report, should assist designers in utilizing HFE inputs. The research is sponsored by the Naval Sea Systems Command as part of its program for Human Factors Engineering Technology for Surface Ships, SF57-525.

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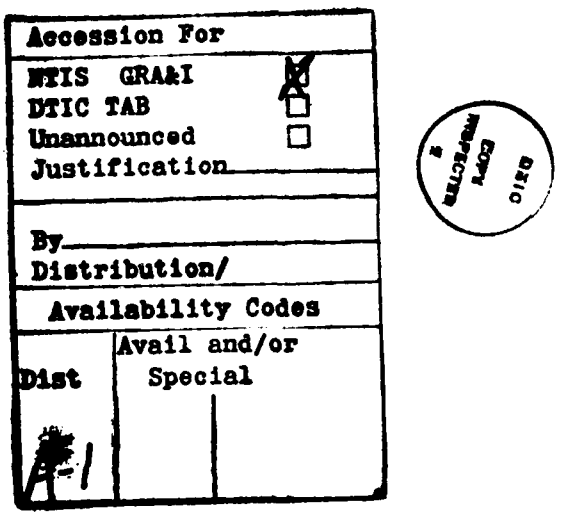

SUMMARY

Problem

Many major Navy weapon systems are developed without the aid of human factors engineering (HFE) inputs, resulting in systems that are difficult to operate, are prone to personnel error, and have reduced operational effectiveness. One reason for this is the lack of an HFE data base to which designers and program managers can refer for answers to behavioral questions that arise during weapon system development and acquisition.

Objective

The overall objective of the project is to develop an HFE data retrieval support system for hardware system acquisition managers and designers. The immediate goal of the effort presented herein was to specify the characteristics of the proposed HFE data base.

Approach

This effort was organized around the development of a data system that would (1) supply information responsive to the needs of a wide variety of users including managers, designers, and HFE specialists, (2) include data of the type presently available in MIL STD 1472C, plus quantitative estimates of human performance data for prediction of personnel effectiveness, maintenance and logistics data, specifications and standards, analytic and evaluational techniques, and (3) include data from operational (Navy) sources not presently found in any HFE data base.

Results

The proposed HFE data system should consist of:

1. Three types of data, with Track 1 consisting of abstracts of individual studies, Track 2 containing data from the same sources presented in a highly synthesized and compressed form, and Track 3 containing all other ancillary information such as HFE specifications and standards. There should be a distinctive format for each track.

2. Data from a wide variety of sources such as fleet exercises, simulators, laboratory studies, subjective judgments, and design-support studies.

3. A three-tier taxonomy for (a) human performance represented by process, function, and generic task and (b) equipment represented by class, type, and subtype.

Recommendations

1. Initiate the development of the HFE system as a multiyear effort in accordance with guidelines presented herein.

2. Implement multiple concurrent contracts for the development of the system.

3. Pursue the development of the operational data sources that should provide much of the information in the system.

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INTRODUCTION

Problem

Many major Navy weapon systems are developed without the aid of human factors engineering (HFE) inputs, resulting in systems that are difficult to operate, are prone to personnel error, and have reduced operational effectiveness. One reason for this is the lack of an HFE data base to which designers and program managers can refer for answers to behavioral questions that arise during weapon system development and acquisition.

Objective

The overall objective of the project is to develop an HFE data retrieval support system for hardware system acquisition managers and designers. The immediate goal of the effort presented herein was to specify the characteristics of the proposed HFE data base.

Background

An HFE data base is the organized comprehensive compilation of quantitative and qualitative data that describe how the behavioral principles function in the design, development and operation of a man-machine system (MSS). The data base may include either quantitative (numerical) data or qualitative (nonnumerical) data derived from quantitative data. In either case, the data refer directly to or imply some human performance involved in the operation and maintenance of the MMS.

There are two reasons for developing an HFE data base. First, HFE specialists need an HFE data base to develop adequate HFE design recommendations. Second, hardware project engineers and designers are reluctant to utilize HFE data and inputs because they are not organized in an easily retrievable form. Consequently, many major Navy weapon systems are developed without HFE advice and data.

The impetus behind the construction of a HFE data base is, therefore, to secure more HFE inputs into Navy hardware system development. The assumption is that, if an effective HFE data base existed, more adequate answers could be given to the many HFE questions that arise during system development. This, in turn, would prompt managers and designers to incorporate these answers into design.

In proposing an HFE data bank, the objection that there are already compilations of data that could satisfy this need must be addressed. In fact, no effective HFE data bank presently exists, despite numerous efforts to develop one. For example, Reed, Snyder, Baran, Loy, and Curtin (1975) attempted to create a data bank based on logistics information available in Air Force documents. Munger, Smith, and Payne (1962) published a data bank based on the probability of error in operating common controls and displays. Blanchard, Mitchell, and Smith (1966) developed a special data bank based on "expert" opinions.

Most compilations of HFE data are in the form of books (e.g., Woodson, 1981; Van Cott & Kinkade, 1972). However, such books fail to satisfy the needs for a HFE data bank because:

1. They are organized as job tools and not in terms of HFE problems for which certain information is needed and can be retrieved.

2. The material they present is not comprehensive, because books are highly selective in the references they cite and the material they present.

3. Books often present summaries of the data rather than the data themselves.

4. Nonspecialists rarely use HFE books as references (Meister & Farr, 1967). Almost all the materials provided for use by nonspecialists are used only by specialists.

5. The material presented comes usually from academic sources rather than from operational situations.

APPROACH

This effort was organized around the development of a data system that would (1) supply information responsive to the needs of a wide variety of users including managers, designers, and HFE specialists, (2) include data of the type presently available in MIL STD 1472C, plus quantitative estimates of human performance data for prediction of personnel effectiveness, maintenance and logistics data, specifications and standards, analytic and evaluational techniques, and (3) include data from operational (Navy) sources not presently found in any HFE data base.

Definition of HFE Data and Data Banks

HFE data describe how personnel perform or might perform in a work-oriented context and how nonbehavioral factors such as equipment, procedures, job design, or manuals affect personnel performance. HFE data are, in most cases, quantitative but may include relevant qualitative material such as:

1. Verbal material describing the context of the studies from which numerical values (data in the "pure" sense) are derived.

2. The conclusions derived from the data.

3. The design implications and recommendations stemming from the conclusions.

4. Ancillary useful information whether or not derived from empirical studies (e.g., listing of HFE specifications and standards, HFE reference texts, etc.).

All of these are considered HFE data in a larger, more general sense.

An HFE data bank is a comprehensive compilation of data organized according to specified principles to answer specified questions. It is not a random collection or a representative sample of data. The data bank's purpose determines which data are incorporated into the bank and which are rejected. All data bearing on the topic or topics for which answers are desired that meet certain criteria of data quality (e.g., size of

subject sample, lack of data confounding, etc.) are incorporated into the bank. A data bank also includes a specified formal and systematic method of using the data bank (e.g., instructions for using, indexing, and retrieving the desired data). Often the data in the data bank have been modified from the form initially derived from the original empirical study. For example, when data from several studies are combined into a single table or graph, the data metric may be modified to a common base; data values may be adjusted--as the developers of the Data Store (Payne & Altman, 1962) did--to make them more representative of the situations to which they will be applied. Another characteristic of the data bank is that the data are presented to the user in a standardized format, although there may be several variations. Therefore, a data bank is much more than merely the presentation of a series of study abstracts, although some part of the data bank may consist of that also. Finally, a data bank was visualized herein as a tool developed for use by HFE specialists and others in the general population and not developed solely to meet the need of an individual researcher.

System Development Questions

Certain questions arise during system development, which starts when a new system is first conceived and ends when it is handed over to the customer for operational use. These questions arise as a natural consequence of the way in which development unfolds. If the data system is to be maximally useful, it should be established to assist in answering these questions, although the questions themselves, being specific to the new system, cannot be answered wholly by the data system. The following questions are modified from Meister (1982):

System Planning Phase

1. What changes in the new system, as distinct from its predecessor, require changes in the number and types of personnel needed to run the system?

2. What changes in the task to be performed in the new system will require changes in personnel selection, training, and operations?

3. In other words, what will be the impact of the new system upon the military's personnel responsibilities and how can this impact be minimized?

Predesign Phase

1. Which of the various design alternatives suggested to satisfy the system requirement is most effective from a human performance standpoint?

2. Will system personnel be able to perform all required functions effectively in the new system in the time available to them? Will they be able to achieve the criterion of required performance if such a criterion exists?

3. What workload will personnel encounter and will any part of that workload be excessive?

4. Given that the new system's error probability has been determined, what are the factors responsible and can it be reduced by changing the design configuration?

Detail Design Phase

1. Which is the better or best of two or more alternative subsystem or component configurations?

2. What level of personnel performance can one achieve with that design configuration and does that level satisfy system requirements?

3. Are there any design elements that could stress personnel and lead to excessive error?

4. Considering the new detailed design configuration, can previous est' *es of number and skill remain unchanged?

5. What kind of training should personnel receive?

6. Are the equipment design and the procedures for its use properl ' nan engineered"? Are there any significant flaws that must be rectified before the ..gn in accepted?

Test and Evaluation Phase

1. Have all the system aspects affected by behavioral variables been properly "human engineered"?

2. Will the operator/maintainer be able to do his/her job effectively with the system as configured?

Operational Testing Phase

1. From the standpoint of personnel performance, does the system meet requirements?

2. What existing design inadequacies must be modified to render the system more effective?

Data Requirements

Blanchard (1973) discussed the kinds of data that will assist in answering these questions:

> A number of various data requirements were identified for two major classes of users: (1) planners/directors/managers (PDM); and (2) human factors and design engineering specialist (HFDE). These needs are listed below with a reference to the associated user group.
>
> (1) System, subsystem and function baseline data on current systems with measures of personnel performance related to overall system performance for use in contrasting current capabilities against potential capability increments of new proposed systems. (PDM)

(2) Data on the relationship between such personnel background factors as educational level, AGCT scores, personnel category level (I, II, III, IV), and on-the-job performance measures on various system tasks for use in performance prediction and assignment. (PDM).

(3) Training time data (formal and OJT) for various personnel classes to reach current or required performance levels on various personnel functions found in current systems. Used in evaluating training impact of new systems. (PDM)

(4) Personnel requirements (standards) data associated with critical personnel activities for various systems. Achievement of standards should ensure attaining a prescribed level of system performance. (PDM)

(5) Personnel readiness or preparedness data for various tasks on operational systems collected over time in order to determine performance levels and degree of performance variability within and between people (positions) and teams. Used for identifying remedial training requirements and for appraising personnel capabilities to perform tasks to the levels required in a new systems approach. (PDM)

(6) Normative personnel performance data for specific system functions for various ships, missions, and operational conditions. Used to assess relative preparedness for feedback in team and individual training efforts and in defining system employment guidelines. (PDM; tactical commanders)

(7) Shipboard work standards and performance time baseline data for such shipboard activities as utilities tasks, administrative support tasks, facilities-maintenance tasks, and watchstanding tasks. (HFDE)

(8) Performance data on a time dimension (response time, execution time, completion time, reaction time) at task, task step, and task element levels of specificity for operator, maintainer, and service-support type tasks. Used primarily in operator work load/time stress analyses and in determining effective operation of display/control consoles. (HFDE)

(9) Continuously distributed capability data illustrating functional relations between various human behavioral processes and equipment, task and environmental parameters. Used in tradeoff analyses and in generating specifications for various system elements in terms of specific parameters with known relations with human performance. (HFDE)

(10) Operator performance data at function and task levels for various "critical" man-machine design interfaces and task/environment conditions (information processing/decision making). Needed to

seek a better match in design between operator and system capabilities to enhance overall effectiveness (level of automation). (HFDE/PDM)

(11) General human capability data at the major function level for various design approaches to enable a design team to compile and review such information and anticipate possible problems that might occur in a new, proposed systems approach which should be given special attention in design. (PDM/HFDE)

(12) Elapsed-time data for human transportation/locomotion activities for various departure/arrival points and shipboard configurations. Used in workload analyses and studies requiring spatial information, transport links, and traverse times under normal and abnormal conditions. (HFDE)

(13) Team performance data for various types of systems, crew configurations, and environmental and operating conditions. Used in studying situations and designing systems in which several individuals perform certain functions in an integrated manner. (PDM/HFDE)

(14) Engineering design data illustrating the relation between a wide range of specific hardware components with various physical characteristics and human performance levels. Used in selecting among alternative hardware components for system use. Also need component cost and reliability data. (HFDE)

(15) To the fullest extent possible, the store should include data on such environmental parameters as temperature, illumination, noise, vibration, ship (aircraft) motion, space limitations, and so forth in relation to performance. Where possible, such factors should be related to a physiological criterion such as hearing loss, visual attenuation, nausea, and so forth. (HFDE)

(16) Personnel cost data and related information to support relative cost/effectiveness tradeoff studies during system design and development and in appraising alternative routes for upgrading current systems. (PDM/HFDE) (pp. 9-11)

Characteristics of Anticipated Users

A data system that is not utilized is in effect worthless. One must therefore be concerned about the anticipated user of the proposed system because the system must be designed to match as much as possible the characteristics of the user.

Blanchard (1972) surveyed the following potential Navy users of a HFE data system:

1. Planners/policymakers.
2. Project/program managers.
3. Hardware design engineers.
4. Reliability/maintainability engineers.
5. HFE specialists.

These job specialities cover a very wide spectrum in terms of amount of behavioral training and knowledge and interest in HFE. However, it can be asssumed that all users, except for HFE specialists, are laymen with minimal interest in and knowledge of HFE. Any HFE data system addressed to both laymen and specialists faces certain difficulties in terms of the demands that can be imposed on each in securing information. Whereas specialists may desire very detailed information about a particular topic and accept complexity and the necessity of analyzing information to secure an answer, laymen prefer their information in simple, easy-to-understand form; directly applicable to their problem; and without the necessity of analyzing data to secure a precise answer. Such a discordance begs for a two-track data format--one designed for laymen and the other, for specialists.

However, equal emphasis need not be given to both laymen and specialists. Any organization with an HFE specialist would probably expect the specialist to supply most of the behavioral data and information. Very few policy makers or design engineers would personally address the HFE data system, if they could simply ask the specialist for the information. From that standpoint, greater emphasis should be placed on having the data system serve HFE specialists rather than the laymen. At the same time, the latter cannot be ignored.

Data Sources

Table 1 presents potential sources of data for the HFE data system.

Data Selection Criteria

Theoretically, the HFE data system should include data from all relevant studies. However, considerations of technical adequacy, cost, and time make such a goal unfeasible. When the data system includes all relevant studies, the value of each study is implicitly accepted as being equal to that of every other study. This is, of course, quite incorrect because some studies have defects that reduce their value. When weak studies are explicitly included in the data system, the system user may wonder why they were included and their presence may confuse him. Some selectivity in the material incorporated into the data system is necessary.

All other things being equal, data from the most recently published studies should be included first. How far back to go in time presents a pragmatic problem. Another problem is that not all studies are of equal value. For instance, what should be done about a study published more than 20 years ago that is a classic in its field? Deference to quality suggests ignoring the arbitrary time limitations in this case. This situation applies mostly to published studies but may also occur when data from a Navy activity was previously published in a report.

One primary criterion of data selection is that the data must contain an explicit or implied reference to human performance. For example, a study dealing with questions of maintenance (e.g., maintenance philosophy such as remove/replace versus remove/replace/repair) might be included in the data system if the maintenance philosophy had implications for the training or performance of naval technicians--the more direct the reference to human performance, the more valuable the study. Of course, the human performance to which the data refer must be work-oriented performance in a man-machine context. A study of decision making processes of subjects solving paper-and-pencil economic problems would not satisfy this criterion.

Table 1

Potential Sources of Data for HFE Data System

Data Source	Limitations/Remarks	Likelihood of Securing Desired Data from Source
1. Operational system using instrumentation that records and measures selected activities automatically (in real time) without human participation and is not visible to system personnel.	Instrumentation can record only control manipulations. Eye movement data could be collected, but it would be prohibitively expensive. Instrumentation provides no cognitive data. The availability of such data is unknown.[a]	Poor
2. Human performance data collected during fleet exercises.	Attempts to collect data during exercises had limited success. Several respondents to Blanchard's survey (1972) indicated such data are not taken too seriously because of the data collection method used. Typically, observers are used, which introduces subjectivity and bias. Most data are collected at the major function level, which typically is too molar to be used in system design applications. Data would be more useful if the data collection agency could participate more with the Navy activity responsible for the conduct of these exercises.	Poor
3. Dynamic simulation studies conducted for personnel training or for evaluating display/control or other system designs.	Simulator studies are considerably more realistic than are most studies, but their cost often limits their use. Often, simulator managers resist using their simulators to collect these data, even though data collection need not interfere with the simulators' primary purpose. The experimental design of the study must ensure gathering of statistically acceptable data.	Poor
4. Military-related laboratory studies conducted to investigate specific problems under controlled conditions.	Laboratory studies are designed to include variables, levels, and conditions that reflect the operational context. Hence, the data obtained would reflect the experimenter's recognition of the need for generalizing to the operational environment. In many instances, the data might be for a specific system.	Good, as these studies are usually published and generally available.
5. "Directed" data collection studies.	Blanchard (1973) proposed this highly specialized potential data source based on the assumptions that (1) a Navy store program eventually will be initiated and (2) such a program would be directed by an administrative agency/activity (e.g., NAVPERSRANDCEN). This agency could routinely determine if any areas within the data store are weak or lack required performance data. If the necessary data are not available from other sources, the agency could initiate and fund its own studies according to detailed specifications.	Poor
6. Experimental research literature.	Considered by most Navy HF specialists to be an essentially invalid source of data for applied work in Navy systems because most experiments are conducted under artificial conditions and also emphasize hypothesis testing (Blanchard, 1972). Studies are often contrived to test only the extremes of a distribution that far exceed any values experienced in practical applications. Therefore, such studies have limited utility in the real world. Such data might be useful if considered carefully within their collection conditions. All moderator variables (performance shaping factors) coded into the data store should be carefully appraised for each study. If such factors are carefully noted, data system users could employ the related data. Despite these reservations, it is anticipated that the proposed data system will be based largely on data from this source because alternative sources are either unavailable or extremely difficult to utilize.	High, although usability will probably vary widely.
7. Subjective judgment studies.	Because of the lack of current human performance data to deal with various human performance problems, various subjective techniques will probably be required to obtain the necessary input data. Techniques involving "expert" judgment have been used by a number of human performance researchers (e.g., Blanchard et al., 1966; Irwin, Levitz, & Freed, 1964; and Embrey, 1981). Those asked to provide judgmental data should be experts on the questions they are asked to answer. Research to assess the validity of such techniques for data collection is quite limited. Conducting formal validation would be highly desirable before such techniques are accepted as potential sources of data system information.	Excellent, if money is available to collect the necessary data.
8. Design-support studies.	Relatively informal studies are sometimes performed during system design and development to obtain guidance on specific design questions or problems. Design-support studies are usually brief, involve minimum time and effort, and seldom report their resulting data formally. If data from these studies can be retrieved and carefully screened, organized, and formatted, these data are a potential source of input data for a data system program. Contractors would need funding to write their studies up according to a data store specification.	Slight
9. Nonperformance data, which are not really data as such.	These sources include information about such topics as personnel cost, HFE specifications and standards, analytical and evaluational techniques, and habitability design principles. Almost all such information is already within the literature; it is merely necessary to dig it out.	Excellent

[a]The operational performance recording and evaluation system (OPREDS), which was developed by the Navy Electronics Laboratory Center, was not equal to its task and was discarded. No other such Navy system is known to exist. At least one civilian system in existence is the General Physics Corporation's performance measurement system for collecting nuclear-power-plant control room trainer data.

The notion that one selects data, accepting some and rejecting some, presupposes a concept that data have relative value: Some data are better than other data. This concept includes the following criteria:

1. Relevance. Refers to the questions that may arise during system development and/or to the particular types of data desired by potential system users.

2. Technical quality. Refers to the confidence one can place in the data derived from a particular study. This confidence is achieved by considering the adequacy of study design, size of subject population, similarity of subject population to Navy population, similarity of study context to Navy operational context, and adequacy of measures taken.

When Blanchard (1972) asked potential users of a data system for the qualities they desire in such a system, they responded that they want, among other things, the capability to judge the validity, applicability, and generalizability of the data. The relevance criterion can deal at least partly with applicability and generalizability, but difficulties arise with the validity criterion. It seems unlikely that, at least initially, the system will provide indications of validity, since the term validity presumes some sort of external check of the data in the operational environment. Almost no behavioral data gathered in laboratory studies have been checked in this manner.

The application of criteria to the selection of data--assuming that it is necessary to select--raises logistical problems of some consequence. Personnel developing the system will need a detailed judgment methodology to make fairly complex judgments of relevance and technical adequacy (e.g., some form of rating scale and some means of aggregating values of multiple criteria). Although this should not pose a serious difficulty, it will require using highly qualified senior personnel for the data selection process and possibly for the further synthesizing of data and writing of abstracts as well. Since these are complex judgments, where the possibility of judgment error is very real, at least two or even three judges will be needed to ensure adequate consistency. All of this increases the cost because reading and evaluating studies takes considerable time and senior personnel are fairly expensive. It is estimated that even skilled personnel will need at least 1 hour for review, analysis, and data abstraction of a single study.

Data Taxonomy

A taxonomy is a system for categorizing or classifying the items in the data base. Without such a taxonomy, it is impossible to create a data base. The taxonomy also serves as a data input and retrieval mechanism because the questions the user asks of the data system must be phrased in terms of the data base taxonomy. Consequently, what is retrieved from the data base is phrased in terms of that same taxonomy.

Development of a data base taxonomy is a heuristic process that is responsive to (i.e., matches) the special questions that data base is designed to answer. There is no universally accepted behavioral taxonomy; indeed, the development of an optimal taxonomy was the subject of a 3-year study program by Fleishman and his colleagues (Fleishman & Stephenson, 1970). Moreover, no single taxonomy is sufficiently comprehensive to encompass all the variables involved in or affecting human performance and HFE; if it were, it would be impossibly complex and cumbersome.

Taxonomies have been developed for human reliability prediction (Munger, Smith, & Payne, 1962; Berliner, Angell, & Shearer, 1964; Meister & Mills, 1971; Finley, Obermayer,

Bertone, Meister, & Muckler, 1970) and for use in classifying error in nuclear power plants (Rasmussen, 1981; Topmiller, Eckel, & Kozinsky, 1982).

RESULTS

Taxonomy

The taxonomy adopted for this effort follows Blanchard's (1973), which was influenced by Berliner et al. (1964) and by Meister and Mills (1971). This three-tier taxonomy permits classification at the process, function, and generic task levels and permits the user to scan the data base at various levels of detail, starting with the molar level and moving down to the more detailed levels.

This taxonomy is a "top-down" scheme, starting as the most molar level of behavior and equipment and progressively breaking that level down to its components. In classifying human performance, the following scheme is used:

1. Process (e.g., perceptual, perceptual-motor, motor, cognitive, etc.).

    a. Function (e.g., visual, auditory, discrete, continuous, etc.).

        (1) Generic task (e.g., detect presence of one or more stimuli).

In classifying equipment, the breakout would be as follows:

1. Class (e.g., visual displays, controls, communications equipment, etc.).

    a. Type (e.g., indicator light, scalar displays, etc.).

        (1) Subtype (e.g., PPI scan, A scan, B scan, etc.).

Any category of the human performance taxonomy can be made to interact with any equipment category so that, for example, the generic task for visual functions (e.g., detect presence of one or more stimuli) can be made to interact with the equipment subtype (e.g., PPI radar scan). Indeed, the two categories of human performance and equipment must interact to provide a meaningful description of an HFE activity, since the latter is defined in terms of both performance and equipment.

The taxonomy classifies only those data descriptive of human performance in interaction with equipment. As can be seen in Appendix A, the HFE data retrieval system will contain much more than human performance data (e.g., analytic and evaluation techniques, applicable instructions and standards, checklists, etc.). Classification of the material in Appendix A follows typical indexing practices.

Data Formats

The proposed HFE data system has three tracks. Track 1, designed specifically for the sophisticated, specialist user, will present the data of each study or empirical data-collection situation on a study-by-study basis in the form of abstracts of the individual studies. Users queried by Blanchard (1972) desired very detailed data so that they could judge the relevance, applicability, and utility of the material presented to them. Track 1 data would presumably satisfy those desires.

More conventional presentation of data involves the synthesis of data into summary statements of the form "Use LED components to display the following . . . ." (Note that such a statement would probably be based on at least one empirical study that would be reported as an individual study in the Track 1 format.) It is assumed that users of the data system who are less sophisticated or are pressed for time will prefer material in this format, which is termed Track 2.

Because the data in Track 2 simply summarize data already presented in longer form in Track 1 and will be cross-indexed to the Track 1 data, users will be able to skip between tracks as desired. They might call out a topic in Track 2 and, desiring more information, might switch to Track 1, calling up all the studies related to the summary data they read in Track 2.

Much of the data system contents (e.g., standards, techniques, etc.; i.e., tutorial material) will not be appropriate to either of these formats and will be placed in what is termed Track 3.

Examples of the format of Tracks 1, 2, and 3 are shown in Appendix B.

Track 1

The data format for Track 1 follows in general that recommended by Blanchard (1972). The individual study, referred to as the data insert (DI), is the basic data storage/retrieval unit of the data system, Track 1.

The DI is organized into three functional sections: (1) index and coding information, (2) data source description and salient performance shaping factors, and (3) data presentation graphics (see Figures B-1--B-3). A description of each DI element follows:

1. DIN. Data insert number preceded by a "1" to represent Track 1.

2. Environment/system (E/ST). Environment within which the data were collected and type of system (if identifiable). Coding is accomplished by combining one or more of the following descriptors:

a. Operational or nonoperational. If operational, circle one of the following items:

(1) Environment.

(a) Airborne (AIR)
(b) Sea surface (SUR)
(c) Ground based (GRB)
(d) Subsurface (SUB)

(2) System.

(a) Attack (ATK)
(b) Antisubmarine warfare (ASW)
(c) Antiair warfare (AAW)
(d) Command/control (CIC)
(e) Communications (COM)
(f) Electronic warfare (ELT)

(g) Mining (MIN)
(h) Navigation (NAV)
(i) Reconnaissance (REC)
(j) Surveillance (SRV)

3. Variable class. Class of independent variables investigated systematically in the DI. Classes and associated codes are:

a. Operational (OP)
b. Equipment (EQ)
c. Task (TS)
d. Personnel (PR)
e. Environmental (EV)

4. Data source. Data in the DI were obtained from the following sources:

a. Operational data/instrumented systems (S-1)
b. Fleet exercise data (S-2)
c. Dynamic simulation (S-3)
d. DoD related HF laboratory studies (S-4)
e. Program-directed data collection studies (S-5)
f. Experimental research literature (S-6)
g. Subjective judgment studies (S-7)
h. Design support studies (S-8)
i. Nonperformance data (S-9)

5. DIN reference. The original report or document from which data were extracted for the DI, which is included in the data system bibliography.

6. Related DINs. An optional category that allows for other DINs to be included in the DIN.

7. Process. The generic function performed by study personnel (e.g., visual, auditory, etc.) that brings the behavior down to a more concrete level.

9. Generic task. Relatively concrete human activity performed by study personnel (e.g., locate stimulus in field with other stimuli).

10. System reference. Study applicable to particular type(s) of Navy system(s).

11. Data description. Description of the situation in which data were collected, including such items as stimuli presented, responses required of personnel, equipment details, presentation rate, etc.

12. Data dimensions. Key aspects of the study used as weighted descriptors for data retrieval.

13. Task factors. Characteristics of the task performed in the study that might modify the performance data collected.

14. Personnel factors. Characteristics of the study personnel that might modify the performance data collected.

15. Environmental factors. Characteristics of the environment in which the data were collected that might have affected those data (e.g., in a display situation, the amount of ambient lighting).

16. Test results. What was learned from this study including specific performance data relationships in graphic/tabular form, significance levels achieved, etc.

17. Interpretation. Conclusions reached from the study.

18. Applicability. Evaluation of the adequacy of the study to serve as the basis of generalization. The kinds of questions the study will answer.

Track 2

Track 2 presents essentially narrative descriptions with graphs, tables, etc. Track 2 contains much of the same data as does Track 1 and the studies referred to in the Track 2 description will be cross-referenced back to DIN items in Track 1; however, the combination and summarization of material in Track 2 does not lend itself to the Track 1 outline type of format. The DINs for Track 2 start with "2." For computerized data retrieval, the Track 2 material will be coded for process, function, generic task, data source, etc.

Track 3

Track 3 includes all other ancillary information such as HFE specifications and standards, analytic and evaluation techniques, etc.

1. DIN. Data insert number preceded by "3" to represent Track 3.

2. Topic.

   a. Title of material
   b. Instructions for data system use
   c. Instructions/standards
   d. Techniques--analytic
   e. Techniques--predictive
   f. Techniques--evaluation
   g. Design principles:
      (1) Controls
      (2) Displays
      (3) Display characteristics
      (4) Workplace
      (5) Anthropometry
      (6) Environment
      (7) Habitability
      (8) Maintainability
   h. Human performance prediction data
   i. Personnel availability and cost
   j. References

Each of these topics may be broken down further as appropriate; for example, by type of control or display, particular environment, or, for anthropometry, the part of the body being considered. There will be no further categorization beyond this sub-breakout.

Data Analyses

Data for the second track will be manipulated to derive generalizations. This will be possible only if the study data were gathered under similar conditions so that it is reasonable to combine the data. It may be necessary to transform the data from several studies into a common metric if a common measure was not initially used. The following data manipulations are possible:

1. Conversion of data to a common metric.

2. Extrapolation of data to new points on a continuum. For example, if the data available describe only points 1-10 on the scale, it may be desirable to extend the curve to extrapolate the data to points 11-15.

3. Modification of data to take into account "performance shaping factors." For example, it is well known that stress changes performance. Based on the information known about stress effects, error rates or task accomplishment indices, etc. may be changed to reflect that stress effect. This was done in the development of the AIR data store (Payne & Altman, 1962) and by Swain and Guttmann (1980).

4. Generalization of data. For example, if considering the data as a whole suggests an inverted U relationship that no single study has demonstrated, it is appropriate for the data system developer to suggest that such a relationship exists because of the burden of the evidence.

In addition, material accompanying the data, such as design recommendations, comments on the quality of the data, confidence in the generalizations, etc., will be provided.

In the first track, data from several studies could be combined if the important aspects of the behavioral data collection situations were similar. As this rarely happens, combining data in the first track seems unlikely. It is possible to combine data in the second track because the approach to the presentation of data is more molar, less finely grained. Since the unsophisticated user is looking more for generalizations than for detail, the "broad brush" treatment of the data permits greater freedom in data manipulation, extrapolation, and generalization.

Prototype Data Base

Emphasis during FY83 was on Track 2 material, which could be developed with less effort and funding than Track 1 material. The scope of the project was also reduced in FY83 by establishing an area of subject matter concentration in which many studies have been performed over the years. Electronic visual displays were selected as an area of data base concentration because their design is important to all modern Navy weapon systems.

The following topics were included in the initial prototype data base:

1. Section 1. Introduction and approach to display design.

2. Section 2. Definitions and specifications of visual display parameters.
3. Section 3. CRT-PPI (planned position indicator) displays.
4. Section 4. CRT-TV (television) displays.
5. Section 5. New technologies (e.g., forward looking infrared).
6. Section 6. Matrix displays.
7. Section 7. Coding of symbols.
8. Section 8. Environmental effects on human performance with displays.
9. Section 9. Human performance using displays in continuous operations.

Data Retrieval Procedures

Hard Copy Retrieval

Initially, the data system will be in book form and user access to the system will be via an index. Because the system is composed of three tracks, there will in fact be three individual indices, one for each track. Each index will have three parts:

1. Subject classification.
2. DIN (data insert number).
3. Page numbers corresponding to the DIN.

In Track 1, retrieval is first by process, function, and generic task. For example, all perceptual (process) DINs are listed. A subclassification under perceptual might be visual-perceptual with its associated DIN and page numbers. The typical user would be most interested in the generic task classification (e.g., locate stimulus in field with other stimuli). Table 2 presents examples of this type of indexing and of indexing by key dimensions, another section of the Track 1 index. The entries in this part of the index would be alphabetized. There would, however, be no subclassifications (e.g., workload under the category of specific displays).

It would, therefore, be possible to identify a DI in terms of process, function, generic task, and all key dimensions. Retrieval would be in terms of subject matter. Having identified the page numbers of the data items of interest, the system users would turn to the pages of interest.

Because the Track 2 indexing scheme closely follows that of Track 1, it would be possible to commingle the indexing for Tracks 1 and 2 with references to process, function, and generic task except that it might complicate the reference process for the user.

Track 3 indexing will follow a traditional indexing procedure in which alphabetized subject matter headings (topic, title, and subtitle) are matched with DINs and page numbers. In Track 3, the subcategories and cross references found in the typical technical book will be permitted.

Computerized Data System

It might be possible to specify the data retrieval characteristics a computerized system should have, but, in view of the considerable development that will be required before such a system can be instituted, it is considered wiser to postpone consideration of this aspect until later.

Table 2

Index by Process, Function, and Generic Task and by Key Dimensions

Classification	DIN[a]	Page Number in Hard Copy
Process, Function, and Generic Task		
Perceptual	11-189	32-115
Visual	11-132	33-75
Locate stimuli	11-110	33-43
Detect stimulus	11-118	44-51
Detect movement	111-128	52-61
Cognitive	100-133	116-159
Information processing	90-133	116-159
Calculate	116-133	142-159
Key Dimensions		
Air traffic control	137	123
Radar	114, 123, 129, etc.	111, 116, 142, etc.
Visual detection of change	153, 162, 179	115, 133, 178
Workload	156, 162, 177, 179	144, 162, 168

[a]DIN = Data insert number.

FUTURE EFFORTS

Long-term Plans

Because of the amount of material to be organized, full-scale development of an effective data retrieval system must be a multiyear effort. Because each of the many specialized subject areas (e.g., controls, displays) that must be considered will require experts to construct, most of the effort must be performed by contractors.

If only material for Tracks 2 and 3 were to be implemented, it might be feasible for a single contractor to develop the necessary materials. Track 1 material, however, requires detailed examination and critique of individual studies and probably no single contractor will have the necessary expertise to handle all aspects of the system. This suggests, then, multiple concurrent contracts for developing individual sections or groups of sections with NAVPERSRANDCEN coordinating the individual contractors and maintaining quality control over their efforts.

It is suggested that the proposed system be developed over the period FY84 through FY88 with funding at the rate of approximately $250,000 to $300,000 each year.

The following steps would be performed:

1. Document main sources and accession information for HFE design support data.

2. Develop procedures for testing the utility of the prototype data system.

3. Conduct initial tests and revise of the prototype data system.

4. Expand data system to additional taxonomic categories.

5. Develop a query and accession system for HFE data sources.

6. Develop and implement techniques for collecting additional behavioral data from operational ships and environments.

7. Develop front-end analytic/evaluating techniques for inclusion in the data system.

8. Develop procedures for computerizing the data system.

9. Develop NAVSEA HFE design standard for implementing HFE design and testing criteria into the design of new ship systems.

10. Implement computerization of full-scale HFE data system.

11. Test computerized data system.

12. Develop and implement procedures for incorporating the HFE data system into the weapon system acquisition process.

Major sections of this report could be incorporated into an informal guide for NAVPERSRANDCEN to use in coordinating the contractors developing sections of the system. NAVPERSRANDCEN would also develop the operational data sources that should provide a very substantial part of the data in the system. Access to these data sources (e.g., fleet exercises, operator/maintainer performance indices, etc.), may be severely restricted because those in charge of Navy ships and ship data may view collecting the desired information as a potentially negative evaluation of their efforts. Hence, using these data sources will require a major effort to secure access to Navy ships and to gather the desired information. However, unless this is done, the human performance data base will consist almost entirely of the experimental research literature. NAVPERSRAND-CEN--not a contractor--must open up the operational data sources. Much of the funding for this project in the "out" years will be required for this effort because the collection of such data is a major effort in itself.

It would also be highly desirable to involve representatives of the potential users of the system in the development effort. The degree to which this involvement will be feasible will depend on user cooperation, which cannot at this time be predicted.

Short-term Plans

Since very substantial funding is required for the implementation of the full-scale system (and the likelihood that all the funding will not become available), it seems reasonable to concentrate on short-term goals, while still pursuing the long-term goals at a somewhat lower level of effort.

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APPENDIX A

OUTLINE OF HFE DATA RETRIEVAL SYSTEM CONTENTS

OUTLINE OF HFE DATA RETRIEVAL SYSTEM CONTENTS

I. Instructions on how to use the information retrieval system.

II. Applicable DoD and Navy instructions/standards. This section will be a listing of the instructions, standards, and specifications that describe or refer to HFE and related areas, or have a bearing HFE or related areas. A brief description of the instruction/standard will be appended to the listed item, but the instruction, standard, etc. will not be reproduced in its entirety.

A. HFE
B. Maintainability
C. Other (e.g., habitability, lighting, safety, etc.)

III. HFE analytic techniques. This section will contain short, outline, step-by-step procedures of major HFE analytic techniques with an example of each. Descriptions will include when the technique should be used and the products of each analysis.

A. General

1. Behavioral questions arising in system development for which analyses are needed (e.g., Will personnel be able to perform system functions adequately?).

B. Specific

1. Function flow analysis
2. Task and job analysis
3. Operational sequence diagrams
4. Time line analysis
5. Information analysis
6. Workload analysis
7. Error mode and effect analysis
8. Link analysis
9. Workplace analysis

IV. HFE evaluation techniques. This section will contain short, outline, step-by-step descriptions of the major evaluation techniques.

A. General

1. Definition of evaluation, phases of system development in which evaluation occurs, types of evaluation.

2. Evaluation questions to be answered in system development.

3. Evaluation measures available (e.g., response time, duration, etc.), purposes for which used, advantages/disadvantages.

4. Types of evaluation tests.

5. DoD/Navy regulations concerning developmental and operational testing.

6. Products to be evaluated (e.g., drawings, procedures).

7. Mockups and how to use them for evaluation.

8. Simulation and simulation models available (e.g., CAFES).

9. Summary of experimental design.

10. Test planning procedures including sample test planning outline.

B. Specific

1. Sample HFE/maintainability checklist.
2. Sample HFE/maintainability questionnaire.
3. Sample HFE/maintainability interview questions.
4. Observational methods (e.g., time sampling).
5. Accident report data.
6. Critical incidents.
7. Opinion methods (e.g., Delphi, paired comparisons, etc.).
8. Self-report methods (e.g., diaries, self-report forms).
9. Automatic measurement methods, (e.g., OPREDS).

V. Principles of control selection (uses a three-tier taxonomy). This section will prescribe the ground rules under which particular types of controls are selected by the designer. Organization of this material is by control type. Information presented includes specific control applications, recommended maximum/minimum dimensions and special characteristics (illustrated by drawings), and error probabilities associated with each type of control.

A. Hand controls

1. Discrete action

a. Pushbuttons
b. Toggle switches
c. Rotary selector switches
d. Multiple pushbuttons
e. Thumbwheels
f. Keysets
g. Keyboards

2. Continuous action

a. Rotary knobs
b. Handwheels
c. Handcranks
d. Levers
e. Joysticks (pressure/displacement)
f. Track ball
g. Thumb controller
h. Sidearm controller
i. Center controller

3. Foot controls

    a. Discrete action
    b. Continuous action

4. Communications equipment

    a. Exterior communications

        (1) Radio--CW
        (2) Radiotelephone
        (3) Radioteletype
        (4) Signal light
        (5) Signal flags
        (6) Amplified voice

    b. Interior communications

        (1) Telephone systems (electrical/sound)
        (2) Announcing systems
        (3) Voice tubes
        (4) Electrical alarm/warning systems
        (5) Electrical indicating/ordering systems

5. Panels and consoles

    a. Panels

        (1) Metal panels
        (2) Transilluminated panels
        (3) Integrated (mated) panels

    b. Configurations

        (1) Contours/slopes of consoles
        (2) Legends/labeling/coding

VI. Principles of display selection/design (uses a three-tier taxonomy). This section will be organized into two parts--type of display and display characteristics. Associated with each will be an error probability and the human performance to be expected with the display and the characteristic.

A. Visual display

    1. Indicator lights (transilluminated)

        a. Single-status
        b. Multiple-status
        c. Lighted pushbutton displays

2. Sequential-access digital readouts

    a. Electromechanical drum counters
    b. Flag counters

3. Random-access digital readouts

    a. Segmented matrices
    b. Cold cathode tubes
    c. Edge-lighted plates
    d. Projection readouts
    e. Back-lighted belt displays
    f. Light-emitting diode (LED) displays

4. Scalar displays (dials, guages, meters)

    a. Moving-pointer, fixed-scale
    b. Fixed-pointer, moving-scale

5. CRT spatial-relation displays

    a. Radar displays
    b. Sonar displays

6. CRT alphanumeric/pictorial displays

    a. Computer output displays
    b. Television output displays (CCTV)
    c. Infrared sensor displays
    d. Low light-level TV displays

7. CRT electronic parameter displays

    a. Waveform displays
    b. Bargraph displays
    c. Analog computer output displays

8. Status displays

    a. Plot boards
    b. Map displays
    c. Projected displays (static/dynamic)
    d. Matrix boards
    e. Large screen displays

9. Hard-copy readout displays

    a. Printers
    b. Recorders
    c. Plotters

10. Film

B. Auditory displays

1. Electromechanical

a. Bells
b. Buzzers
c. Horns
d. Sirens

2. Electronic

a. Electronic tones/signals
b. Recorded signals/directions (tape)

C. Visual display characteristics

1. Specific

a. Alphabet characters
b. Alphabet words
c. Numeric characters
d. Numeric groups
e. Alphanumeric words
f. Alphanumeric groups
g. Unstructured (e.g., PPI)
h. Coded
i. Photographic
j. Map type
k. Tabular
l. Graphic

2. General

a. Color
b. Background characteristics
c. Overall display size
d. Stimulus size
e. Phosphor characteristics
f. Dynamic characteristics

(1) Static
(2) Moving

g. Resolution
h. Density of stimuli
i. Stimulus number
j. Number of stimulus channels
k. Number of levels of information per channel
l. Rate of display change
m. Frequency of stimulus presentation

VII. Design of individual and multiman workplaces

A. General

1. Principles of workplace design analysis
2. Layout principles
3. Standardization
4. Safety
5. Visibility factors
6. Anthropometric factors

B. Specific

1. Control/display arrangement
2. Console design
3. Working areas
4. Seats
5. Doors and hatches
6. Stairs/ladders/ramps
7. Traffic spaces

VIII. Performance of behavioral functions (uses a three-tier taxonomy). This section will describe the personnel performance to be expected with general behavioral functions and, consequently, is organized by individual functions. Associated with each of the functions listed below are: (a) error probability, (b) limiting values (maximum/minimum) (e.g., smallest stimulus that can be perceived), and (c) performance as a function of relevant variables for which data exist. Heavy emphasis will be given to graphic and tabular material.

A. Perceptual processes

1. Visual

a. Detect presence of one or more stimuli (radar target, indicator light).
b. Detect movement of one or more stimuli.
c. Detect change in basic stimulus presentation (status, alphanumeric).
d. Detect variation in stimulus characteristics (color, shape, size).
e. Recognize stimulus characteristics and identify/classify stimulus types.
f. Locate stimulus in a field containing other stimuli of varying similarity.
g. Discriminate two or more stimuli on basis of relative characteristics.
h. Read materials and obtain information/instructions.
i. Read displays and obtain alphanumeric information.

2. Auditory

a. Detect presence of one or more aural stimuli (sonar signal, aural alarm).

b. Recognize stimulus characteristics and identify/classify stimulus types.

c. Detect a variation or change in stimulus characteristics (pitch, amplitude, harmonics).

d. Discriminate two or more stimuli on basis of relative characteristics (pitch, amplitude, quality, harmonics).

3. Tactile

a. Identify control(s) by discriminating among various shape codes.

B. Perceptual-motor processes

1. Discrete

a. Activate/set one or more controls according to displayed information.

b. Mark position of object(s) on a device/surface according to displayed information.

c. Manipulate control to position one or more stimuli at a discrete location according to displayed information.

d. Change stimulus characteristics by manipulating control (gain, brightness).

e. Introduce new stimuli or remove old stimuli by manipulating control (information display updating).

2. Continuous

a. Adjust control(s) to maintain coincidence of two moving stimuli (pursuit tracking).

b. Adjust control(s) to compensate for deviation in one moving stimulus (compensatory tracking).

c. Input data/information by manipulating one or more controls (alphanumeric keyboard).

d. Align two or more stimulus presentations to achieve balanced or steady-state condition.

e. Regulate the level or rate of a process, event, or output according to displayed information.

C. Motor processes

1. Manipulative

a. Connect/disconnect mated objects.

b. Set control(s) to predetermined position.

c. Install material/item according to established procedure.

d. Record information manually using writing instrument.

e. Position object in a particular physical orientation to another object(s).

f. Open/close access doors/hatches/plates.

g. Remove/replace components from larger units.

2. Movement

a. Transport object from one point to another.
b. Lift, move, set object.
c. Locomote from one point to another.
d. Throw an object from one point to another.
e. Exert force on an object/body (push, pull, press, grip).

D. Cognitive processes

1. Information processing

a. Code/decode stimuli according to known rules and principles.

b. Calculate/compute indices/values using arithmetic.

c. Categorize/classify stimuli or data according to known characteristics.

d. Compare two or more calculated values and take prescribed action.

e. Interpolate/extrapolate known values to estimate or predict event or status.

f. Analyze information or stimuli where alternatives are not specified as part of problem information.

2. Decision-making/problem-solving

a. Select course of action from two or more options based on stated rules, principles, guidelines.

b. Select course of action from alternatives when routine application of rules would be inadequate for optimal choice.

c. Predict the occurrence of an event or condition using various sources of displayed and recalled information.

d. Estimate the characteristics and/or causal relationships of stimuli/events by transforming existing principles into specialized, higher-order guidelines.

E. Communication processes (primary purpose of activity)

1. Request information

a. Request instructions/information using voice communication device.

b. Reqest instructions/information on a face-to-face basis.

c. Request instructions/information using coded communication/interrogation device.

2. Provide information

a. Provide advice/instructions/information using voice communication device.

b. Provide advice/instructions/information on a face-to-face basis.

c. Provide advice/instructions/information using coded communication device.

3. Listen to information

a. Listen to instructions/information using voice communication device.

b. Listen to instructions/information on a face-to-face basis.

IX. Anthropometric tables. This section will contain tables of anthropometric values for selected parameters and is not intended to present a complete set of such tables since their number would be excessive. Tables will be divided into static and dynamic dimensions.

X. Effects of environmental factors on performance. This section will be described in terms of the individual factors listed below. Each factor will include the limiting values (e.g., lethal threshold, threshold of pain) and human performance of a general function like vigilance as determined by one or more factor dimensions (e.g., direction of acceleration).

A. Temperature
B. Noise
C. Lighting
D. Vibration
E. Acceleration
D. Vibration
E. Acceleration
F. Air movement
G. Diurnal variations

XI. Habitability design for ship living and work spaces. This section presents available design principles for ship habitability design.

A. Habitability of living spaces

1. Berthing
2. Sanitary spaces
3. Messing
4. Environmental control (e.g., lighting, temperature, noise, etc.)
5. Color and furniture
6. Habitability design processes

B. Habitability of working spaces

XII. Principles of maintainability design. This section presents data and principles for the internal design of equipment and the personnel implications of that design.

A. Principles of maintainability design

1. Accessibility
2. Packaging
3. Component labeling
4. Connectors, conductors, and fasteners
5. Automatic test equipment
6. Maintenance procedures
7. Maintenance job aids

B. Maintainability prediction

1. Available methods
2. Mean time to repair for common equipment components
3. Troubleshooting
4. Probabilities of task accomplishment for preventive and corrective maintenance

XIII. Prediction of individual/team performance. This section describes available methods for predicting the human performance reliability (HPR) of system personnel for new systems and also includes available HPR data bank information.

A. Available methods

1. Technique for human error rate prediction
2. Siegel's multidimensional scaling method
3. AIR data bank

B. HPR data for:

1. Man-machine components (e.g., controls, displays, interfaces, etc.).

2. Modifying factors such as age, sex, training, experience, intelligence, stress, and illness.

3. Examples of how to perform HPR predictions.

XIV. Personnel availability and cost

A. Personnel availability data
B. Personnel costs per rating

XV. References. This section will contain additional reading for each section above.

APPENDIX B

EXAMPLES OF FORMAT FOR TRACKS 1, 2, AND 3

EXAMPLE OF TRACK 1 FORMAT

DIN: 163

E/ST: Nonoperational

Variable class: TS

Data source: S-6

DIN reference: Thackray et al. The effect of increased monitoring load on vigilance performance using a simulated radar display. Ergonomics, 1979, 529-539.

Related DINs: N/A

Process: Perceptual

Function: Visual detection

Generic task: Detect critical stimulus in midst of constantly moving targets.

System reference: Simulated air traffic control containing computer-generated alphanumerics.

Data description: Simulated ATC display (17-inch CRT) in console. Simulated radar sweep line made one complete clockwise revolution every 6 seconds. Targets were small rectangular "blips" representing aircraft locations. Adjacent to each target was an alphanumeric data block with two rows of symbols: top row (two letters, three numbers) identified aircraft, bottom row (six numbers) indicated altitude and ground speed. A total of 48 male university students were randomly assigned to three groups of equal size, each group differing only in the number of targets (4, 8, or 16). Critical signals were presented during each half hour of the 2-hour session. Subjects responded to critical signal by pressing button and holding light pen over target.

Data dimensions: (Weights assigned on the basis of relative importance: major (1) or minor (2))

Visual detection of change (1)
Radar (1)
Air traffic control (1)
Alphanumeric stimuli (2)
Detection latency (1)
Target density (1)
Workload (1)
Performance decrement over time (1)
Laboratory study (2)
Male student subjects (2)
Simple task, low stress (2)

Task factors:

Complexity: simple
Duration: 2 hours

Load stress: low
Time stress: low

Personnel factors:

Skill level: low
Motivation: weak
Experience: none
Training: none

Environmental factors: Indirect lighting; level of illumination at display, 21.5 lux.

Test results: Figure B-1 provides mean detection latencies for three target densities as a function of successive 30-minute periods. Detection latencies increase over time for the 16-target condition, but not for other target conditions. Errors are virtually nonexistent over all conditions.

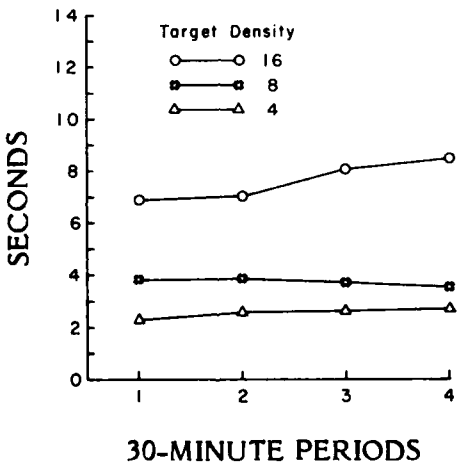

Figure B-1. Mean detection latencies for the three target density conditions.

Interpretation: For applicable situations, no performance decrement either in detection latency or error is to be anticipated for moderate target density (4-8 targets) over 2 hours of monitoring. With a large target density (16), there is a slight increase in detection latency with monitoring time, but the increase is not excessive.

Applicability: This study is applicable to air traffic control situations in which the visual stimuli are alphanumeric, the work loading is low, the performance measured is detection of change, and the variable of interest is performance decrement as a function of target density.

EXAMPLE OF TRACK 2 FORMAT

DIN: 2773

E/ST: Nonoperational

Variable class: EQ

Data source: S-6

DIN reference:

Process: Perceptual

Function: Visual

Generic task: Identify symbols on CRT

System reference: Use of CRT. Effect of TV raster scan and vertical resolution on symbol resolution.

Test results:

How many active TV lines per symbol height are required to display symbols?

Figure B-2 shows the results of three studies seeking the relationship between number of active scan lines per symbol height and the accuracy and speed of symbol identification. All indicate that a minimum of 10 raster scan lines per symbol height are needed for highly accurate identification. In fact, some reduction in accuracy is noted when resolution is reduced from 12 to 10 lines per symbol height.

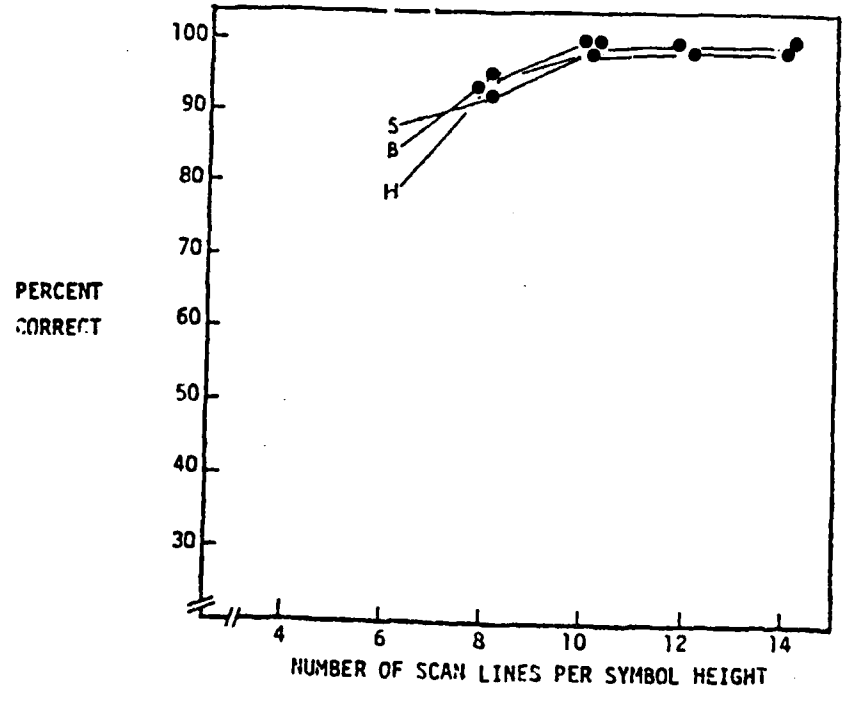

Figure B-2. The functional relationship between number of TV scan lines/symbol height and identification accuracy (adapted from the data of DIN 16, 38, 92).

Rate of identification exhibits a relationship similar to that for accuracy, as shown in Figure B-3.

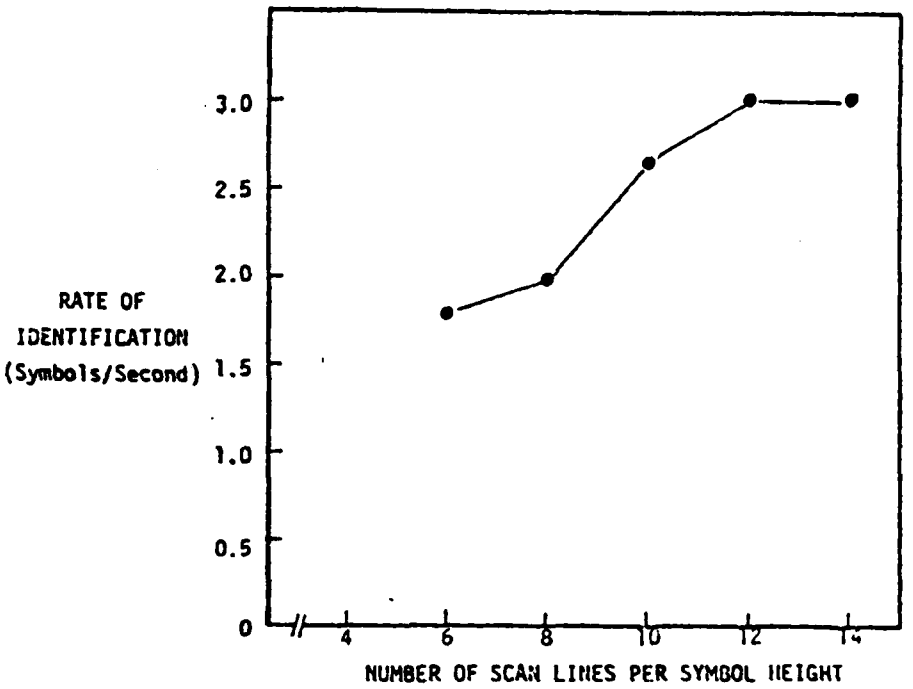

Figure B-3. The functional relationship between number of TV scan lines/symbol height and rate of identification (adapted from the data of DIN 16, 38, 92).

EXAMPLE OF TRACK 3 FORMAT

DIN: 342

Topic: Techniques: Analytic

Timeline Analysis

Human factors specialists use timelines to predict the incidence of time and errors for two purposes. First, they permit an appraisal of time-critical activities to verify that all necessary events can be performed. Second, they provide an integrated task-time chart to assess the occurrence of incompatible tasks and to serve as a baseline for workload evaluation.

The most common source of material for a timeline analysis is a detailed level functional flow diagram in which tasks are allocated to operators. Timelines are most effectively used during the concept formulation phase of system development, after DSARC I, but before DSARC II. They require comparatively little time to develop and are only moderately complex. They are equally useful for analysis of gross detailed operator procedures and can be used either for individual operator or team tasks, as long as all the tasks are placed on a single time base.

A typical timeline chart is shown in Figure B-4. Each timeline must be related to a higher level functional requirement. The functional flow title and number should be indicated on the timeline sheet for reference. Other information such as location of the function and the type of function are desirable. Each of the subfunctions or tasks are numbered and listed along the timeline.

Time Line Sheet	Function	Location (If Applicable)	Type of Maintenance (If Applicable)
2.3.3	Perform Sonar Detection (SQS-95)		

Source of Function	Function and Corresponding Tasks (If Applicable)	Time (Minutes)
	Assistant Sonar Operator	2345 2350 2355 2400 0005 0010 0015 0020 0025 0030
2.3.3.1	Rec. order to search	
.2	Insert parameters	
.3	Test return	
.4	Monitor syst. status	
.5	Monitor display	
.6	Observe BT data	
.7	Activate auto functions	
.8	Observe data	
.9	Enter data	
.10	Set threshold	
.11	Aural alarm	
.12	Secure alarm	
.13	Select mode	
.14	Analyze data	
.15	Transfer target to classification	

Figure B-4. Sample timeline sheet.

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